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A Tele-Robotic Garden on the World Wide Web

University of Southern California

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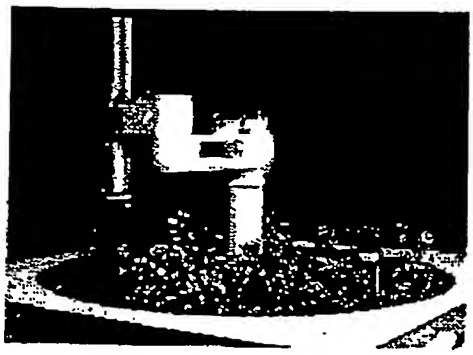
The WWW has started a revolution in global communication. Novice computer users are now able to navigate the Internet to discover vast seas of archival information. The WWW also has the potential to facilitate remote control of physical devices such as cameras and robot arms. To our knowledge, USC's Mercury Project was the first to permit tele-robotic manipulation of a remote environment. In that project users could direct compressed air into a sandbox to excavate buried artifacts. Online almost continuously for six months starting in August 1994 the Mercury project was accessed by over 50,000 unique sites around the world. The idea of tele-robotic manipulation was independently pursued by Taylor's team in Australia and subsequently by many others including groups at Lehigh and UC Berkeley.

Our latest project, the Tele-Garden, allows WWW users to view and interact with a remote garden filled with living plants. Users can plant, water, and monitor the progress of seedlings via the tender movements of an Adept robot arm:

http://telegarden.aec.at/



In addition raising issues about online communities the Tele-Garden offers three innovations over previous sites:

1. Multi-tasking to eliminate operator queue,
2. customizable user interface, and
3. user-choreographed mpeg videos.

Whereas the Mercury Project required operators to wait up to 20 minutes on a queue for a 5-minute turn to control the robot, we realized we could in effect multi-task the robot to allow "simultaneous" access. After X-Y coordinates are received from a client, a command is sent to move the robot arm, a color CCD camera takes an image, the image is compressed based on user options such as color resolution, lighting, and size, and then returned to the client. All coding is done in C and the 1-second cycle time of the Adept arm allows us to respond to requests in 5-10 seconds depending on load.

The user interface can be customized based on a large variety of options, including what information is

presented and in what format with color and resolution scales etc. This information is encrypted in the URL so that client's can save their "preferences" by simply saving the url on their bookmark list.

Another novel feature is the ability to request a video "time-lapse" of a single view over several weeks or a "pan" along a user specified trajectory. The video is recorded during non-peak hours and compressed into mpeg late at night. User's can vote on their own and other's videos in a Movie page.

Planting and watering are accomplished with a series of pneumatic actuators. A pump can be activiated to spray one tablespoon of water into the garden at a specified point. When planting is requested, the system lowers a "foot" via pneumatic cylinder and digs a small hole, then a seed is sucked up from a tray at the edge of the garden, the seed is then dropped into the hole. Finally the foot is lowered again to cover the hole, and a burst of water is applied. As of Feb 1996, well over 1000 seeds have been planted.

A primary criterion was that the system be reliable enough to operate 24 hours a day and survive user attempts at sabotage. Our secondary goal was to create an evolving WWW site that would encourage repeat visits by users to nurture their own plants. In this way, the project emulates humankind's movement from nomadic tribes to permanent villages and towns.

The WWW system is driven mostly from an Intel Pentium based workstation equipped with an image capture board, running the Linux operating system and the NCSA HTTPD web server software. Robot control is achieved through a serial port connection to the robot controller. The interactive WWW interface options are created via a large custom Common Gateway Interface program written in C. It maintains databases of user and system status, log and chat comments, movie creation etc.

The Tele-Garden went online in August, 1995. As of February 1996, the Tele-Garden home page was accessed over 46,000 times and over 4900 users have registered as "members" of the garden cooperative. A few stalwart members are regular visitors. Over 600,000 move requests have been made to the robot. Current statistics are plotted daily.

The Tele-Garden will be online for one year until June 1996. It was exhibited at the 1995 Interactive Media Festival, SIGGRAPH, Festival for Interactive Arts, and the New Voices - New Visions (NVNV) New Media Competition. The installation was awarded First prize in the Festival for Interactive Arts (FIVA) and the Kobe Prize at the Interactive Media Festival. The project is supported by the USC Annenberg Center for Communications, USC School of Engineering, and Adept Technology, Inc.

Notes

Goldberg is on leave from USC to the Dept of Industrial Engineering and Operations Research at UC Berkeley. Santarromana is with UC Irvine Art Dept. Bekey, Gentner, and Wiegley are with the Computer Science Department. Sutter is with the Center for Scholarly Technology.

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